5-18-2008

Higgs Production via b bbar -> H in Hadron Colliders

Nikolaos Kidonakis
Kennesaw State University, nkidonak@kennesaw.edu

Recommended Citation
Kidonakis N. 2008. Higgs production via b bbar -> H in hadron colliders. Deep Inelastic Scattering, DIS.

Higgs Production via $b\bar{b} \to H$ in Hadron Colliders

Nikolaos Kidonakis[1]

Kennesaw State University, Physics #1202
1000 Chastain Rd., Kennesaw, GA 30144-5591

Abstract

I present NNNLO collinear and soft gluon corrections for Higgs production via the process $b\bar{b} \to H$. I show that the collinear corrections dominate and contribute large enhancements to the cross section at both the Tevatron and the LHC.

1 Introduction

The discovery of the Higgs boson is a goal of paramount importance at hadron colliders. The search for the Higgs continues at the Tevatron and will soon start at the LHC. The main Standard Model production channel at both colliders is $gg \to H$. The channel $b\bar{b} \to H$ is relatively small in the Standard Model but is numerically important in the MSSM at high $\tan\beta$.

The process $b\bar{b} \to H$ has very simple color structure and kinematics, essentially the same as for the Drell-Yan process [1]. The complete QCD corrections are known to NNLO [2]. The collinear [3] and soft gluon [3, 4, 5] corrections can be calculated to higher orders. Here we present results for these corrections through NNNLO. It is shown at NLO and NNLO that the soft-gluon approximation is inadequate; purely collinear terms must also be added to obtain a good approximation to the full QCD corrections. We calculate the complete soft corrections and the leading and some subleading purely collinear terms at NNNLO [3], and show that these higher-order corrections provide additional significant enhancements to the cross section at both the Tevatron and the LHC.

2 NNNLO collinear and soft corrections

We first provide the analytical form of the soft and collinear corrections. We define $s = (p_b + p_{\bar{b}})^2$ and $z = m_H^2/s$, with m_H the Higgs mass. As we approach threshold, $z \to 1$. The n-th order soft and collinear corrections in the partonic cross section are of the form

$$\hat{\sigma}^{(n)}_{S+C}(z) = \sum_{k=0}^{2n-1} S_k^{(n)} \left[\frac{\ln^k(1-z)}{1-z}\right]_+ + \sum_{k=0}^{2n-1} C_k^{(n)} \ln^k(1-z)$$

where the first and second sums are, respectively, the soft corrections and the purely collinear corrections.

[1]Presented at DIS 2008, London, England, April 7-11, 2008

The NLO soft and collinear gluon corrections are given explicitly by

$$\hat{\sigma}^{(1)}_{S+C}(z) = F^B \frac{\alpha_s(\mu_R^2)}{\pi} \left\{ 4C_F \left[\frac{\ln(1-z)}{1-z}\right]_+ - 2C_F \ln\left(\frac{\mu_F^2}{m_H^2}\right)\left[\frac{1}{1-z}\right]_+ \right.$$
$$\left. - 4C_F \ln(1-z) + 2C_F \ln\left(\frac{\mu_F^2}{m_H^2}\right) + 2C_F \right\}$$

where F_B is the Born term, $C_F = 4/3$, and μ_F is the factorization scale. The NNLO soft and collinear gluon corrections are

$$\hat{\sigma}^{(2)}_{S+C}(z) = F^B \frac{\alpha_s^2(\mu_R^2)}{\pi^2} \left\{ 8C_F^2 \left[\frac{\ln^3(1-z)}{1-z}\right]_+ + \cdots - 8C_F^2 \ln^3(1-z) + \cdots \right\}$$

and the NNNLO soft and collinear gluon corrections are

$$\hat{\sigma}^{(3)}_{S+C}(z) = F^B \frac{\alpha_s^3(\mu_R^2)}{\pi^3} \left\{ 8C_F^3 \left[\frac{\ln^5(1-z)}{1-z}\right]_+ + \cdots - 8C_F^3 \ln^5(1-z) + \cdots \right\}$$

where for brevity we only show the leading terms.

We now present results for the cross sections for $b\bar{b} \to H$ at the Tevatron, with $\sqrt{S} = 1.96$ TeV, and the LHC, with $\sqrt{S} = 14$ TeV. We use the bottom quark parton distribution functions (pdf) from the MRST2006 NNLO set of parton densities [6]. We are particularly interested in the relative size of the higher-order contributions to the total cross section. In the results below we denote the factorization and renormalization scales by μ.

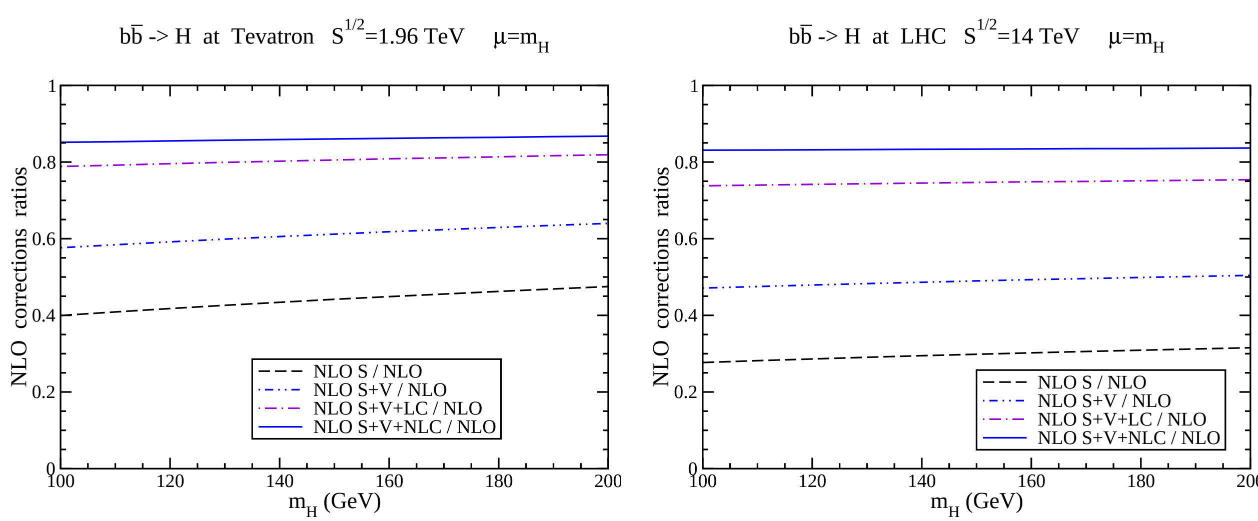

Figure 1: The NLO ratios for $b\bar{b} \to H$ at the Tevatron (left) and the LHC (right).

In Figure 1 we show the contribution of various terms to the complete NLO corrections for Higgs production at the Tevatron (left) and the LHC (right), setting $\mu = m_H$. In this figure NLO denotes the $\mathcal{O}(\alpha_s)$ corrections only (i.e. without the Born term). The curve marked NLO S / NLO denotes the fractional contribution of the NLO soft (S) corrections to the total NLO corrections. We see that this contribution does not surpass 48% at the Tevatron and 32% at the LHC and thus the soft-gluon approximation is by itself inadequate. Adding on the virtual terms, the soft plus virtual (S+V) corrections still do not provide a good approximation to the full corrections. Further adding collinear corrections substantially improves the situation. When leading collinear (LC) logarithms are included, the resulting S+V+LC approximation accounts for about 80% of the total NLO corrections at the Tevatron and 75% at the LHC. If we further add the next-to-leading collinear (NLC) terms the approximation (S+V+NLC) gets even better, reaching around 85% of the total corrections, at both the Tevatron and the LHC. Clearly the inclusion of collinear terms greatly improves the approximation in both cases, and in particular it is important to include the NLC terms.

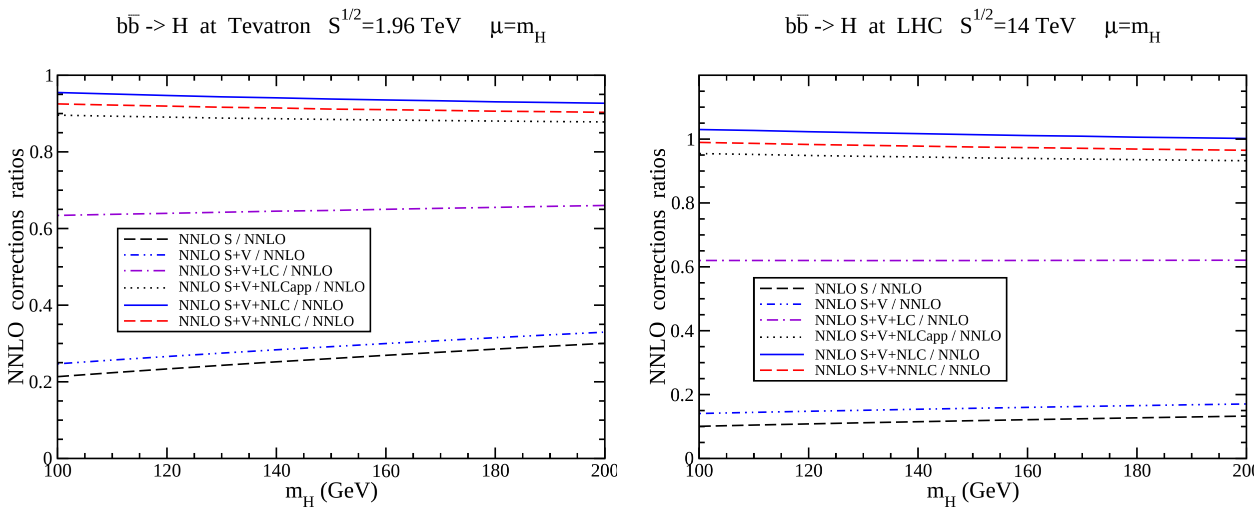

Figure 2: The NNLO ratios for $b\bar{b} \to H$ at the Tevatron (left) and the LHC (right).

In Figure 2 we show the contribution of various terms to the complete NNLO corrections for $b\bar{b} \to H$ at the Tevatron (left) and the LHC (right), with $\mu = m_H$. In this figure NNLO denotes the $\mathcal{O}(\alpha_s^2)$ corrections only (i.e. without the Born term and NLO corrections). The curve NNLO S / NNLO denotes the fractional contribution of the NNLO soft corrections to the total NNLO corrections. At the Tevatron and the LHC the soft contribution is rather small, in fact even smaller than at NLO. The same is true of the S+V contribution. The additional inclusion of the leading collinear logarithms accounts for about 60% of the total NNLO corrections at both the Tevatron and the LHC, which is better but still not satisfactory. However, the further inclusion of the next-to-leading collinear logarithms improves the approximation significantly. The effect of the NLC terms is much more important at NNLO than at NLO, and thus the NLC terms are needed to achieve a good approximation. We also plot a curve (S+V+NNLC) that in addition includes the next-to-next-to-leading collinear terms (NNLC). We see that the NNLC terms alone do not make a large contribution, and that the S+V+NNLC results approximate the exact NNLO corrections very well.

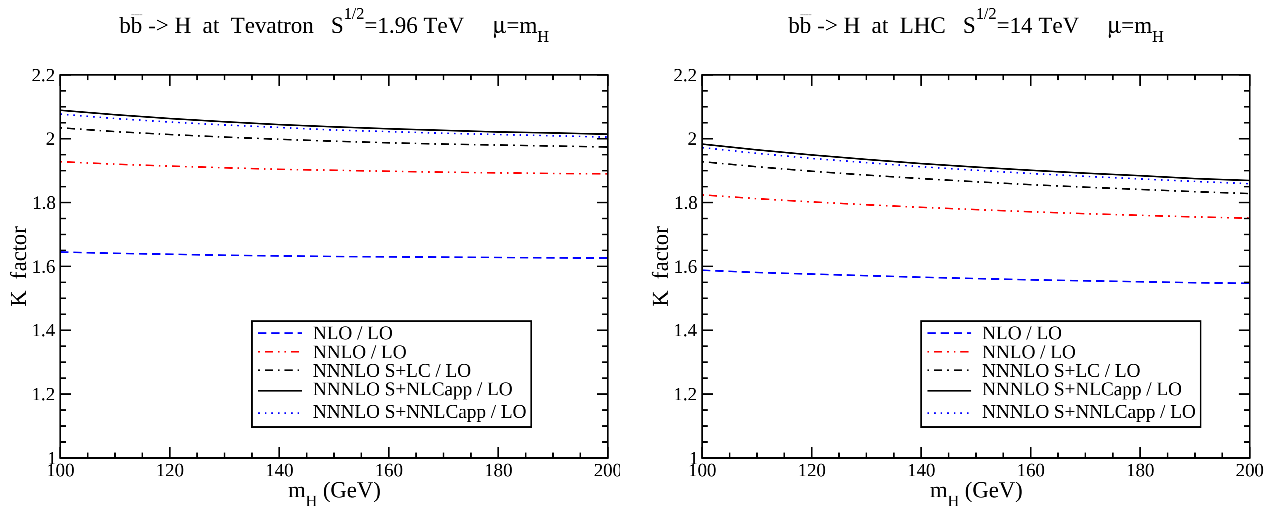

Figure 3: The K factors for $b\bar{b} \to H$ at the Tevatron (left) and the LHC (right).

Figure 3 shows the K factors at the Tevatron (left) and the LHC (right), with $\mu = m_H$. Here N^{k}LO cross section means the Born term plus all the corrections through $\mathcal{O}(\alpha_s^k)$. The NLO / LO curve shows that the complete NLO corrections increase the LO result by around 60% at both the Tevatron and the LHC. Inclusion of the complete NNLO corrections futher significantly increases the cross section: the NNLO K factor is around 1.9 at the Tevatron and 1.8 at the LHC. Finally, we include the complete soft and approximate collinear corrections at NNNLO, which provide further significant enhancements. We plot one curve with the soft and leading collinear (S+LC) terms, another curve with the soft and approximate NLC (S+NLCapp) terms, and a third with the soft and approximate NNLC (S+NNLCapp) terms. We note that the difference between the S+LC and S+NLCapp curves is small, and between the S+NLCapp and S+NNLCapp curves it is much smaller. The NNNLO S+NNLCapp K factor is between 2.00 and 2.08 at the Tevatron and between 1.86 and 1.97 at the LHC for Higgs masses between 100 and 200 GeV. The conclusions from the study of the soft and collinear terms at NLO and NNLO at both the Tevatron and the LHC gives us confidence that the NNNLO S+NNLCapp curves provide a good approximation of the complete NNNLO cross section.

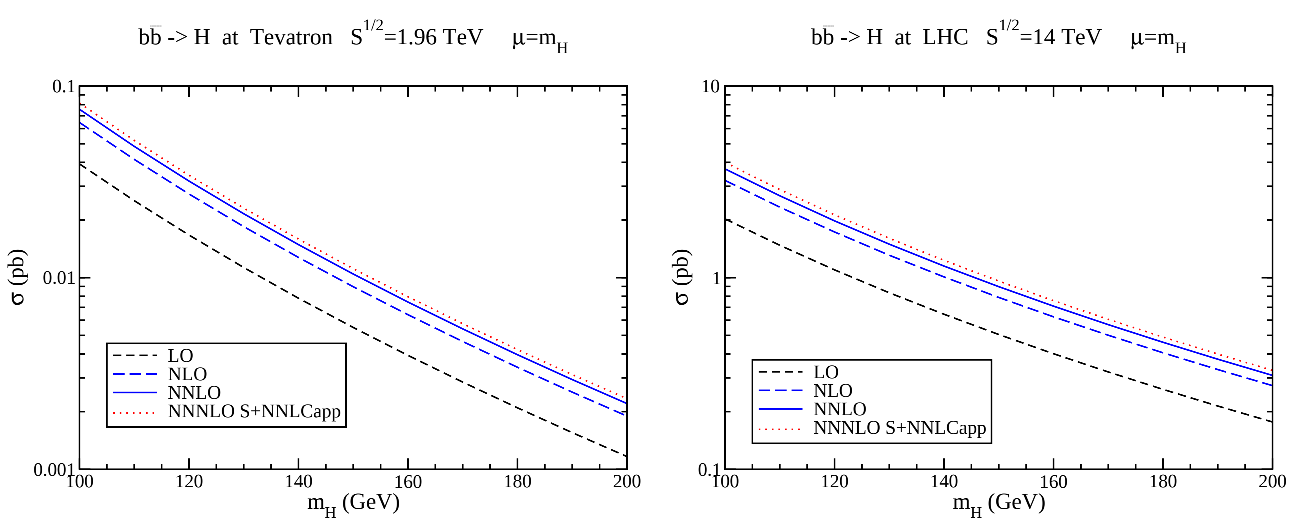

Figure 4: The cross section for $b\bar{b} \to H$ at the Tevatron (left) and the LHC (right).

In Figure 4 we plot the Standard Model cross sections for $b\bar{b} \to H$ at the Tevatron (left) and the LHC (right). We show LO, NLO, NNLO, and NNNLO S+NNLCapp results for $\mu = m_H$.

Acknowledgements

This work was supported by the National Science Foundation under Grant No. PHY 0555372.

References

[1] Slides:
http://indico.cern.ch/contributionDisplay.py?contribId=120&sessionId=15&confId=24657

[2] R.V. Harlander and W.B. Kilgore, Phys. Rev. **D68**, 013001 (2003) [hep-ph/0304035].

[3] N. Kidonakis, Phys. Rev. **D77**, 053008 (2008), arXiv:0711.0142 [hep-ph].

[4] N. Kidonakis, Phys. Rev. **D73**, 034001 (2006) [hep-ph/0509079].

[5] V. Ravindran, Nucl. Phys. **B752**, 173 (2006) [hep-ph/0603041].

[6] A.D. Martin, W.J. Stirling, R.S. Thorne, and G. Watt, Phys. Lett. **B652**, 292 (2007), arXiv:0706.0459 [hep-ph].